Biochemical Genetic Stock Compositions of Chum Salmon Fisheries in Southern British Columbia, 1981-1983

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BIOCHEMICAL GENETIC STOCK COMPOSITIONS OF CHUM SALMON FISHERIES IN SOUTHERN BRITISH COLUMBIA, 1981-1983

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ABSTRACT

Beacham, T. D., R. E. Withler, A. P. Gould, and M. K. Farwell. 1985. Biochemical genetic stock compositions of chum salmon fisheries in southern British Columbia, 1981-1983. Can. Tech. Rep. Fish. Aquat. Sci. 1356: 23 p.

We used biochemical genetic variants to estimate stock compositions of chum salmon (Oncorhynchus keta) in 9 fisheries in southern British Columbia. Our estimates of relative abundance of Fraser River chum salmon in upper Johnstone Strait were later confirmed by a test fishery in the Fraser River. At least 60% of the chum salmon migrating through Johnstone Strait in October in 1982 and 1983 were derived from rivers on the east coast of Vancouver Island and the mainland inlets. Chum salmon that were genetically similar to those spawning in the mainstem Fraser River migrated past the Albion sampling site in early October, late November, and early December of 1982. Chum salmon from Washington and the Fraser River were intercepted in commercial fisheries held off Nanaimo in 1982 and Cape Lazo in 1983. Chum salmon from Howe Sound were estimated to be present in a test fishery conducted on Roberts Bank, south of the mouth of the Fraser River, suggesting that a portion of Howe Sound stocks migrate through Juan de Fuca Strait.

Key words: British Columbia, chum salmon, Georgia Strait, Johnstone Strait, Oncorhynchus keta, stock identification

RESUME

Beacham, T. D., R. E. Withler, A. P. Gould, and M. K. Farwell. 1985. Biochemical genetic stock compositions of chum salmon fisheries in southern British Columbia, 1981-1983. Can. Tech. Rep. Fish. Aquat. Sci. 1356: 23 p.

Les auteurs ont utilisé des variants génétiques au niveau biochimique pour estimer la composition des stocks de saumon kéta (Oncorhynchus keta) composant neuf pêcheries du sud de la Colombie-Britannique. Les estimations de l'abondance relative du kéta du fleuve Fraser dans la partie supérieure du détroit de Johnstone ont été confirmées ultérieurement par une pêche expérimentale effectuée dans le fleuve Fraser. Au moins 60 % des kétas qui ont migré par le détroit de Johnstone en octobre 1982 et 1983 provenaient de cours d'eau de la côte est de l'île Vancouver et d'inlets continentaux. Les kétas génétiquement semblables aux reproducteurs du cours principal du fleuve Fraser sont passés au lieu d'échantillonnage à Albion au début d'octobre, à la fin de novembre et au début de décembre en 1982. Des saumons venant de l'Etat de Washington et du fleuve Fraser ont été pris au cours de pêches commerciales réalisées au large de Nanaïmo en 1982 et de Cape Lazo en 1983. On croit que des kétas de la baie Howe étaient présents dans une pêche exploratoire effectuée sur le banc Roberts, au sud de l'embouchure du Fraser; ceci porte à croire qu'une partie des stocks de la baie Howe migrent par le détroit Juan de Fuca.

Mots-clés: Colombie-Britannique, saumon kéta, détroit de Géorgie, détroit de Johnstone, Oncorhynchus keta, identification de stock

INTRODUCTION

Chum salmon (Oncorhynchus keta) returning to spawn in their natal streams tributary to Johnstone Strait, Georgia Strait, and the Fraser River migrate primarily through Johnstone Strait (Anderson and Beacham 1983). Depending on chum salmon abundance, there can be extensive net fisheries in Johnstone Strait where, given the temporal overlap in migration of major stocks (Anderson and Beacham 1983), the potential for overexploitation of less productive stocks in the mixed stock fishery is significant. There also can be net fisheries in Georgia Strait and in-river fisheries in the Fraser River.

Management of the commercial fisheries has traditionally been based on total chum stock abundance. However, differing productivities of chum salmon stocks migrating through Johnstone Strait makes knowledge of stock compositions necessary in order to ensure that less productive stocks are not overexploited in mixed stock fisheries. In 1981, a program of stock identification was undertaken in order to provide in-season estimates of stock compositions so that more discrete harvesting of stocks could be attempted. The major stocks that contribute to the commercial fisheries were sampled on the spawning grounds, and electrophoretic, meristic, and morphometric characters were surveyed from each stock. The results of the 1981 and 1982 surveys of meristic and morphometric characters were outlined by Beacham et al. (1983), and the results of the 1981-1983 spawning ground electrophoretic surveys were outlined by Beacham et al. (1985). Only the electrophoretic characters have proved useful for stock identification for in-season management.

During the course of the chum salmon stock identification program, a number of fisheries were sampled in order to estimate stock compositions of the catch. In the present report, we use the electrophoretic characteristics of the individual stocks that were sampled on the spawning grounds to estimate stock compositions in mixed fisheries.

MATERIALS AND METHODS

Chum salmon on the spawning grounds were sampled from 33 rivers tributary to Johnstone Strait, Georgia Strait and the Fraser River (Fig. 1). Heart, liver, and muscle tissue were collected from each individual and stored at -20°C until electrophoretic analysis. Eight single and two duplicated loci were screened. Full details of the electrophoretic analysis have been outlined by Beacham et al. (1985). Seven loci were used in the estimation of stock compositions. Those screened from muscle were: isocitrate dehydrogenase (Idh-1), a peptidase utilizing leucyl-glycyl-glycine as a substrate (Lgg), malic enzyme (Me), and 6-phosphogluconate dehydrogenase (6-Pg). Those screened from heart were alpha-glycerol-phosphate (Agp-2) and phospho-manno-isomerase (Pmi). Idh-3 was screened from the liver. For the

fisheries for which in-season estimates of stock compositions were required (Johnstone Strait, Cape Lazo), samples were brought to the Pacific Biological Station, electrophoretic analysis conducted, and stock compositions estimated for use in in-season management. Tissue samples collected from other fisheries were frozen for later electrophoretic analysis by a consultant. We verified the scoring of all gels from complete photographic records.

Chum salmon were sampled from 9 fisheries in southern British Columbia (Fig. 2). The Johnstone Strait purse seine test fishery was sampled on a weekly basis in 1982 (9 weeks) and 1983 (8 weeks). In 1982 the weekly sample was collected on 1 day (5 or 6 sets with a purse seine) but in 1983 the weekly samples were collected over a 3 to 5 day period. The Fraser River gillnet test fishery was also sampled on a weekly basis in 1982. This test fishery was conducted near Albion in the mainstem Fraser River. Samples were collected over a 1-day period for 10 weeks. All samples from other fisheries were collected with gillnets. Sampling times and details for the fisheries sampled in 1981 and 1982 were outlined by Beacham et al. (1983). Details of the test fishery at Cottonwood in the Fraser River have been outlined by Beacham and Starr (1982).

Estimates of stock compositions were derived by the method of Fournier et al. (1984). Thirty-five baseline samples were used to estimate stock compositions in the mixtures. The Nimpkish River chum salmon stock migrates through upper Johnstone Strait considerably later than other stocks (Anderson and Beacham 1983), and thus would not have been present in any of the mixtures. It was eliminated from the analysis, leaving 32 stocks included from our surveys (Beacham et al. 1985). Chum salmon stocks from Washington that have been screened electrophoretically were pooled in 3 regions: north Puget Sound, south Puget Sound, and Hood Canal (Wishard 1980), and the pooled estimate of genotypic frequencies of chum salmon in each region was used as a single baseline sample, giving a total of 35 samples for estimating stock compositions. The estimated contribution of stocks from a region was determined as a sum of all component stocks in the region. For example, the proportion of Fraser River chum salmon in a mixture was the sum of the proportions of the 12 stocks surveyed on the spawning grounds from the Fraser River system. Standard deviations of the estimated proportion were derived by constructing 100 new mixtures from the original mixture, estimating stock compositions of each new mixture, and determining the standard deviations of each proportion for the 100 mixtures. Each new mixture was constructed by randomly sampling 90% of the original mixture without replacement.

RESULTS

JOHNSTONE STRAIT

The upper Johnstone Strait test fishery was sampled on a weekly basis during September and October in 1982 and 1983. Allelic frequencies of

the 7 loci used for estimating stock compositions in the samples are outlined in Table 1. Allelic frequencies of Lgg were not available for the 1982 survey. In 1982, chum salmon in Johnstone Strait were more abundant than in 1983 (Table 2), and extensive commercial fisheries were conducted in Johnstone Strait. In 1982, chum salmon from both the Fraser River and Washington reached a relative peak of abundance in upper Johnstone Strait for the week ending September 23rd, and a greater peak of abundance for the week ending October 21st (Fig. 3). Chum salmon were most abundant at Cottonwood, an in-river test fishery near the mouth of the Fraser River, from October 15th to October 30th. The relative peak of Fraser River chum salmon present in Johnstone Strait on September 23rd apparently reached the Fraser River by October 15th, taking about three weeks for the migration. Previous tagging studies indicated a 21-day migration timing between these sites (Anderson and Beacham 1983). Fraser River chum salmon comprised at least 30% of chum salmon present in Johnstone Strait before September 10th (Table 3), but given the low abundance of chum salmon in Johnstone Strait during that period (Table 2), they formed a very minor component of the total return to the Fraser River. Chum salmon stocks from the east coast of Vancouver Island and the mainland inlets were most abundant in upper Johnstone Strait during the first week of October in 1982. They generally comprised at least 60% of the chum salmon in upper Johnstone Strait during October (Table 3).

The Johnstone Strait test fishery was again sampled on a weekly basis in 1983. The peak of Fraser River chum salmon abundance in upper Johnstone Strait occurred about September 28th, and a subsequent peak at the in-river test fishery on the Fraser River near Cottonwood occurred about October 19th (Fig. 4). This 21-day interval of migration for Fraser River chum salmon from upper Johnstone Strait to the Fraser River again agrees closely with the results of tagging studies (Anderson and Beacham 1983). The decline in chum salmon abundance at Cottonwood after October 19th was more rapid than would have been predicted from the abundance of Fraser River chum salmon in upper Johnstone Strait after September 28th (Fig. 4). Commercial fisheries held off Cape Lazo in mid-October intercepted some Fraser River chum salmon, presumably causing this more rapid in-river decline of Fraser River chum salmon abundance.

Fraser River chum salmon comprised at least 40% of the chum salmon in upper Johnstone Strait during September 1983 (Table 4). As in 1982, chum salmon from the east coast of Vancouver Island and the mainland inlets comprised at least 60% of the chum salmon present in Johnstone Strait during October in 1983. The peak abundance in upper Johnstone Strait of this group of chum salmon occurred during the first week in October in both 1982 and 1983. Chum salmon from Washington reached a relative peak of abundance in upper Johnstone Strait about September 25th in 1982 and October 5th in 1983. Fraser River chum salmon reached a relative peak of abundance in upper Johnstone Strait during late September in both years.

FRASER RIVER

The Fraser River test fishery at Albion was sampled on a weekly basis in 1982 for 10 weeks (Table 5). The sampling indicated that chum salmon

that spawn in the mainstem of the Fraser River migrated past Albion during early to mid-October and again in late November and early December (Fig. 5). Chum salmon were not sampled on the spawning grounds farther upstream than the mainstem sample obtained near Hope, British Columbia. However, some chum salmon do migrate upstream past Hope, and it may be that these upriver stocks or other mainstem chum salmon which generally spawn earlier than the ones surveyed, migrate past Albion in early October. Chum salmon from the Vedder River were most abundant at Albion from late October to late November (Fig. 5), at times comprising over 30% of the weekly sample (Table 6). Chum salmon from the Chilqua Slough region were most abundant at Albion during early November. Chum salmon from the Stave, Chehalis, Weaver, and Alouette Rivers comprised most of the remainder of the stocks in October.

GEORGIA STRAIT

A number of test fisheries were conducted in Georgia Strait during 1981-1983 (Table 7). Test fisheries conducted near the Big Qualicum River in 1981 and 1982 indicated that less than 10% of the fish sampled were of Fraser River origin (Table 8), and Vancouver Island stocks dominated the samples. Similar results had previously been observed from tagging programs in the region (Anderson and Beacham 1983). A commercial fishery conducted near Nanaimo in 1982 harvested a high proportion of bright and semi-bright chum salmon, which prompted fisheries management concerns. A sample taken on November 12th indicated that 40% of the fish originated from Washington and 20% from the Fraser River (Table 8). The frequency of Agp^{100} in chum salmon from this fishery was the lowest of any fishery surveyed in southern British Columbia during 1981-1983 (Table 7). Chum salmon from Washington have lower Agp^{100} frequencies than do chum salmon from British Columbia (Beacham et al. 1985). This fishery presumably intercepted chum salmon from Washington that migrated through upper Johnstone Strait about October 20th (Fig. 3). A two or three-week migration period would place these fish at the appropriate time and location to be intercepted in the Nanaimo fishery. The analysis also suggested that Fraser River chum salmon comprised a substantial portion of the sample.

A test fishery conducted in Satellite Channel in 1982 near the Cowichan River indicated that few Fraser River or Washington chum salmon were present in the area (Table 8). Similar results have been indicated by tagging studies (Anderson and Beacham 1983). A test fishery conducted in 1982 southwest of Cape Lazo near the Puntledge River and in Lambert Channel indicated that few Fraser River chum salmon were present in the region. During October 10-18, 1983, commercial fisheries were conducted to the southeast of Cape Lazo, closer to the middle of Georgia Strait than the area sampled in 1982, and they intercepted substantial numbers of bright and semi-bright chum salmon. Prompted by fisheries management concerns, we collected a sample from the area in which the fishery was conducted, and found that Fraser River chum salmon comprised 36% of the sample. Interceptions of Fraser River chum salmon in this fishery probably explain the rapid decline in chum salmon abundance at the in-river Fraser test fishery at Cottonwood after October 19th (Fig. 4).

When all chum salmon sampled at Albion in the Fraser River during 1982 were considered as a group, 83% of the sample was identified as originating from the Fraser River (Table 8). However, computer simulations described by Beacham et al. (1985) indicated that the Fournier et al. (1984) model underestimated the true proportion of Fraser River chum salmon present in a sample when Fraser River chum salmon comprised in excess of 70% of the sample. As the Albion test fishery was sampling 100% Fraser River chum salmon, the estimate of 83% is indicative of the bias present in the estimated Fraser River proportion. Chum salmon from the Fraser River and Washington were sufficiently distinctive to allow chum salmon from these two regions to be discriminated. A test fishery conducted on Roberts Bank near the mouth of the Fraser River indicated that Fraser River chum salmon were the most abundant group (63%), but that chum salmon from Howe Sound stocks (Squamish River drainage, Indian River) were also present (Table 5). A portion of these stocks presumably migrates through Juan de Fuca Strait to return to their natal spawning grounds. A small proportion of the sample (10%) was identified as originating from Washington State.

DISCUSSION

The chum salmon stock identification program was initiated in 1981 in response to concern about possible overexploitation of less productive stocks, particularly Fraser River chum salmon in commercial fisheries in southern British Columbia. Chum salmon stocks on the east coast of Vancouver Island were being enhanced by artificial propagation, and given the overlapping migration timing of Fraser River, Vancouver Island, and mainland stocks through Johnstone Strait (Anderson and Beacham 1983), all unenhanced chum salmon could be overexploited in Johnstone Strait fisheries. It was necessary to develop methods of stock identification that would allow Fraser River chum salmon to be distinguished from other stocks. The results of the survey of biochemical genetic variants indicated that Fraser River chum salmon were sufficiently distinct to allow them to be discriminated from other stocks (Beacham et al. 1985). Electrophoretic analysis was then used to provide in-season (Johnstone Strait, Cape Lazo) and post-season estimates of stock compositions for use in fisheries management.

The migratory timing and relative abundance of Fraser River chum salmon in Johnstone Strait were determined by sampling the Johnstone Strait test fishery in 1982 and 1983. An estimated peak of Fraser River chum salmon abundance in Johnstone Strait was confirmed about 21 days later by a peak at the in-river Fraser River test fishery at Cottonwood in both 1982 and 1983. This result provides an independent confirmation that we were able to estimate the relative abundance of Fraser River chum salmon in Johnstone Strait.

Chum salmon from Washington were estimated to have reached a relative peak in abundance in Johnstone Strait about September 23rd in 1982 and October 5th in 1983. This 10-day to 2-week delay in migration through

Johnstone Strait was also reflected by a similar delay in timing of escapements (J. Ames, Wash. Dept. Fish. pers. comm.). The delay in migration during 1983 may be a result of warmer water temperatures owing to the 1983 El Nino. A slight delay in timing of southern British Columbia chum salmon stocks through Johnstone Strait was also evident.

Two samples from fisheries (Nanaimo, Cape Lazo) were obtained in response to unusually high proportions of bright and semi-bright chum salmon in the predominately dark catches. In both instances, the estimated stock compositions are about what one might have expected in order to account for the high proportions of bright chum salmon in the catches. Chum salmon from Washington in the Nanaimo fishery and from Washington and the Fraser River in the Cape Lazo fishery are still sufficiently far enough away from their natal spawning grounds that they have not undergone the marked change in coloration characteristic of spawning chum salmon.

Biochemical genetic variation has previously been used to estimate stock compositions in fisheries for sockeye salmon (O. nerka) (Grant et al. 1980) and chinook salmon (O. tshawytscha) (Miller et al. 1983). The results from our surveys of chum salmon indicate that screening of biochemical genetic variants can provide both in-season estimates of stock composition for use in fisheries management and post-season estimates for use in stock reconstruction.

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Table 1. Allelic frequencies of chum salmon from weekly sampling in Johnstone Strait during 1982 and 1983. The frequency of the most common allele at a locus is designated 100 and others are assigned numbers according to their mobility relative to the common allele. N is sample size.

		Idh-1	6-Pg	Me	Agp-2	Idh-3					Pmi	Lgg
Date	N	100	100	100	100	100	25	40	85	110	100	100
						1982 Sampling						
Sept. 04	109	0.931	1.000	0.875	0.964	0.628	0.064	0.266	0.041	0.000	0.925	-
Sept. 10	110	0.907	1.000	0.840	0.968	0.692	0.063	0.197	0.048	0.000	0.856	-
Sept. 17	110	0.931	1.000	0.824	0.972	0.651	0.075	0.241	0.033	0.000	0.882	-
Sept. 23	110	0.903	0.995	0.801	0.948	0.661	0.041	0.216	0.083	0.000	0.849	-
Oct. 02	118	0.933	0.996	0.798	0.939	0.654	0.054	0.246	0.046	0.000	0.933	-
Oct. 07	120	0.917	1.000	0.756	0.956	0.688	0.034	0.235	0.043	0.000	0.857	-
Oct. 15	120	0.941	0.996	0.752	0.947	0.567	0.112	0.271	0.050	0.000	0.895	-
Oct. 21	42	0.917	1.000	0.793	-	0.667	0.036	0.286	0.012	0.000	0.927	-
Oct. 28	120	0.900	1.000	0.802	0.914	0.630	0.050	0.269	0.046	0.004	0.898	-
						1983 Sampling						
Sept. 08-09	77	0.917	1.000	0.840	0.948	0.562	0.055	0.322	0.062	0.000	0.883	0.850
Sept. 14-16	101	0.896	0.995	0.842	0.965	0.613	0.067	0.258	0.062	0.000	0.901	0.844
Sept. 20-22	100	0.929	0.995	0.808	0.942	0.566	0.112	0.291	0.031	0.000	0.935	0.847
Sept. 27-30	100	0.929	0.985	0.815	0.968	0.548	0.096	0.266	0.090	0.000	0.918	0.809
Oct. 03-06	99	0.899	0.990	0.808	0.954	0.601	0.071	0.247	0.081	0.000	0.924	0.818
Oct. 10-13	100	0.945	0.995	0.815	0.965	0.650	0.065	0.210	0.075	0.000	0.920	0.780
Oct. 18-21	100	0.939	0.985	0.732	0.955	0.581	0.051	0.318	0.051	0.000	0.924	0.803
Oct. 24-26	100	0.935	0.995	0.765	0.940	0.603	0.062	0.304	0.031	0.000	0.940	0.800

Table 2. Weekly mean catch/set (pieces) of chum salmon in the purse seine test fishery in upper Johnstone Strait in 1982 and 1983. Total number of sets made during the week is in parentheses.

Week ending	Catch Set	
	1982	1983
Sept. 3	27 (4)	
Sept. 10	76 (16)	20 (15)
Sept. 17	292 (14)	32 (17)
Sept. 23	371 (25)	71 (18)
Sept. 30	584 (19)	124 (29)
Oct. 7	343 (12)	155 (28)
Oct. 14	514 (17)	107 (29)
Oct. 21	542 (7)	78 (22)
Oct. 28	154 (9)	27 (14)

Table 3. Estimated stock compositions (proportions) of chum salmon in the weekly test fishery in upper Johnstone Strait during 1982. Standard deviations of estimated proportions are in parentheses.

Date	Group					
	Fraser River		Other Canadian		Washington State	
Sept. 4	0.575	(0.107)	0.397	(0.105)	0.031	(0.015)
Sept. 10	0.304	(0.060)	0.599	(0.061)	0.100	(0.020)
Sept. 17	0.131	(0.094)	0.807	(0.094)	0.064	(0.023)
Sept. 23	0.268	(0.062)	0.611	(0.066)	0.125	(0.036)
Oct. 2	0.091	(0.045)	0.904	(0.051)	0.006	(0.021)
Oct. 7	0.009	(0.004)	0.988	(0.010)	0.006	(0.009)
Oct. 15	0.249	(0.038)	0.753	(0.039)	0.003	(0.006)
Oct. 21	0.410	(0.139)	0.589	(0.139)	0.004	(0.001)
Oct. 28	0.152	(0.082)	0.716	(0.096)	0.134	(0.034)

Table 4. Estimated stock compositions (proportions) of chum salmon in the weekly test fishery in upper Johnstone Strait during 1983. N is the number of fish sampled each week. Standard deviations of estimated proportions are in parentheses.

Date	N	Group		
		Fraser River	Other Canadian	Washington State
Sept. 8-9	77	0.454 (0.071)	0.540 (0.069)	0.006 (0.011)
Sept. 14-16	101	0.419 (0.090)	0.539 (0.088)	0.041 (0.024)
Sept. 20-22	100	0.439 (0.075)	0.560 (0.075)	0.002 (0.001)
Sept. 27-30	100	0.408 (0.097)	0.495 (0.102)	0.097 (0.034)
Oct. 3-6	99	0.237 (0.058)	0.575 (0.059)	0.189 (0.034)
Oct. 10-13	100	0.225 (0.058)	0.723 (0.061)	0.052 (0.021)
Oct. 18-21	100	0.133 (0.045)	0.786 (0.051)	0.081 (0.025)
Oct. 24-26	100	0.298 (0.053)	0.702 (0.053)	0.000 (0.001)

Table 5. Allelic frequencies of chum salmon from weekly sampling in the Fraser River during 1982. Fifty fish were sampled weekly. The frequency of the most common allele at a locus is designated 100 and others are assigned numbers according to their mobility relative to the common allele.

	Idh-1	6-Pg	Me	Agp-2	Idh-3				Pmi	Lgg
Date	100	100	100	100	100	25	40	85	100	100
Oct. 06	0.949	0.987	0.795	-	0.641	0.128	0.192	0.038	0.795	0.808
Oct. 14	0.935	0.980	0.840	0.950	0.600	0.100	0.240	0.060	0.890	0.875
Oct. 20	0.896	1.000	0.867	0.929	0.550	0.110	0.310	0.030	0.837	0.837
Oct. 27	0.896	1.000	0.890	0.930	0.532	0.128	0.319	0.021	0.880	0.813
Nov. 03	0.890	1.000	0.830	0.889	0.500	0.090	0.370	0.040	0.910	0.780
Nov. 12	0.850	1.000	0.852	0.963	0.540	0.080	0.330	0.040	0.890	0.775
Nov. 19	0.880	1.000	0.780	0.980	0.660	0.080	0.200	0.060	0.890	0.780
Nov. 25	0.920	0.960	0.870	0.960	0.550	0.150	0.260	0.040	0.830	0.830
Dec. 03	0.920	1.000	0.820	0.918	0.540	0.070	0.300	0.090	0.870	0.840
Dec. 09	0.910	0.990	0.840	0.964	0.670	0.090	0.210	0.030	0.860	0.811

Table 6. Estimated stock compositions (proportions) of chum salmon in the weekly test fishery at Albion in the Fraser River during 1982. Standard deviations of estimated proportions are in parentheses. Fifty fish were sampled weekly.

	Group			
Date	Vedder	Chilqua	Mainstem and Wahleach	Other Fraser
Oct. 6	0.001 (0.008)	0.001 (0.000)	0.255 (0.096)	0.743 (0.089)
Oct. 14	0.005 (0.004)	0.000 (0.001)	0.205 (0.094)	0.790 (0.094)
Oct. 20	0.187 (0.157)	0.075 (0.056)	0.009 (0.005)	0.729 (0.177)
Oct. 27	0.313 (0.132)	0.146 (0.075)	0.003 (0.005)	0.538 (0.162)
Nov. 3	0.173 (0.091)	0.401 (0.062)	0.010 (0.031)	0.416 (0.098)
Nov. 12	0.350 (0.115)	0.228 (0.077)	0.011 (0.035)	0.411 (0.137)
Nov. 19	0.150 (0.130)	0.000 (0.001)	0.017 (0.041)	0.833 (0.127)
Nov. 25	0.012 (0.030)	0.001 (0.008)	0.476 (0.083)	0.511 (0.086)
Dec. 3	0.037 (0.047)	0.001 (0.001)	0.228 (0.111)	0.734 (0.118)
Dec. 9	0.063 (0.085)	0.001 (0.002)	0.230 (0.107)	0.706 (0.122)

Table 7. Allelic frequencies of chum salmon from different fisheries in southern British Columbia during 1981-1983. The frequency of the most common allele at a locus is designated 100 and others are assigned numbers according to their mobility relative to the common allele. N is sample size.

Fishery.	Year	N	Idh-1	6-Pg	Me	Agp-2	Idh-3					Pmi	Lgg
			100	100	100	100	100	25	40	85	110	100	100
Big Qualicum	1981	551	0.945	0.999	0.775	-	0.647	0.054	0.261	0.038	0.000	-	-
Big Qulaicum	1982	25	0.960	1.000	0.840	0.940	0.560	0.020	0.360	0.060	0.000	0.920	0.860
Nanaimo	1982	98	0.867	1.000	0.756	0.908	0.570	0.081	0.285	0.059	0.005	0.858	0.808
Cowichan	1982	191	0.925	1.000	0.751	0.963	0.572	0.051	0.314	0.064	0.000	0.901	0.794
Puntledge	1982	255	0.928	0.996	0.747	0.972	0.612	0.062	0.269	0.058	0.000	0.935	0.826
Texada Island	1982	116	0.891	0.991	0.750	0.967	0.647	0.032	0.243	0.078	0.000	0.932	0.932
Fraser River	1982	500	0.903	0.992	0.839	0.947	0.575	0.102	0.275	0.046	0.001	0.871	0.813
Cape Lazo	1983	100	0.910	1.000	0.825	0.930	0.595	0.060	0.310	0.035	0.000	0.895	0.785
Roberts Bank	1983	188	0.902	0.995	0.856	0.941	0.577	0.051	0.311	0.061	0.000	0.915	0.800

Table 8. Estimated stock compositions (proportions) of chum salmon in test fisheries conducted in southern British Columbia. Locations of the fisheries are outlined in Figure 2. Standard deviations of the estimated proportions are in parentheses.

Location	Year	N	Group		
			Fraser River	Other Canadian	Washington State
Big Qualicum	1981	551	0.062 (0.024)	0.898 (0.024)	0.040 (0.012)
Big Qualicum	1982	25	0.086 (0.071)	0.913 (0.071)	0.001 (0.001)
Nanaimo	1982	98	0.202 (0.086)	0.406 (0.082)	0.391 (0.078)
Cowichan	1982	191	0.059 (0.025)	0.940 (0.025)	0.001 (0.002)
Puntledge	1982	255	0.068 (0.016)	0.863 (0.029)	0.070 (0.027)
Texada Island	1982	116	0.025 (0.016)	0.969 (0.019)	0.006 (0.014)
Fraser River	1982	500	0.826 (0.048)	0.178 (0.047)	0.003 (0.005)
Cape Lazo	1983	100	0.358 (0.086)	0.525 (0.084)	0.117 (0.057)
Roberts Bank	1983	188	0.631 (0.056)	0.266 (0.053)	0.104 (0.021)

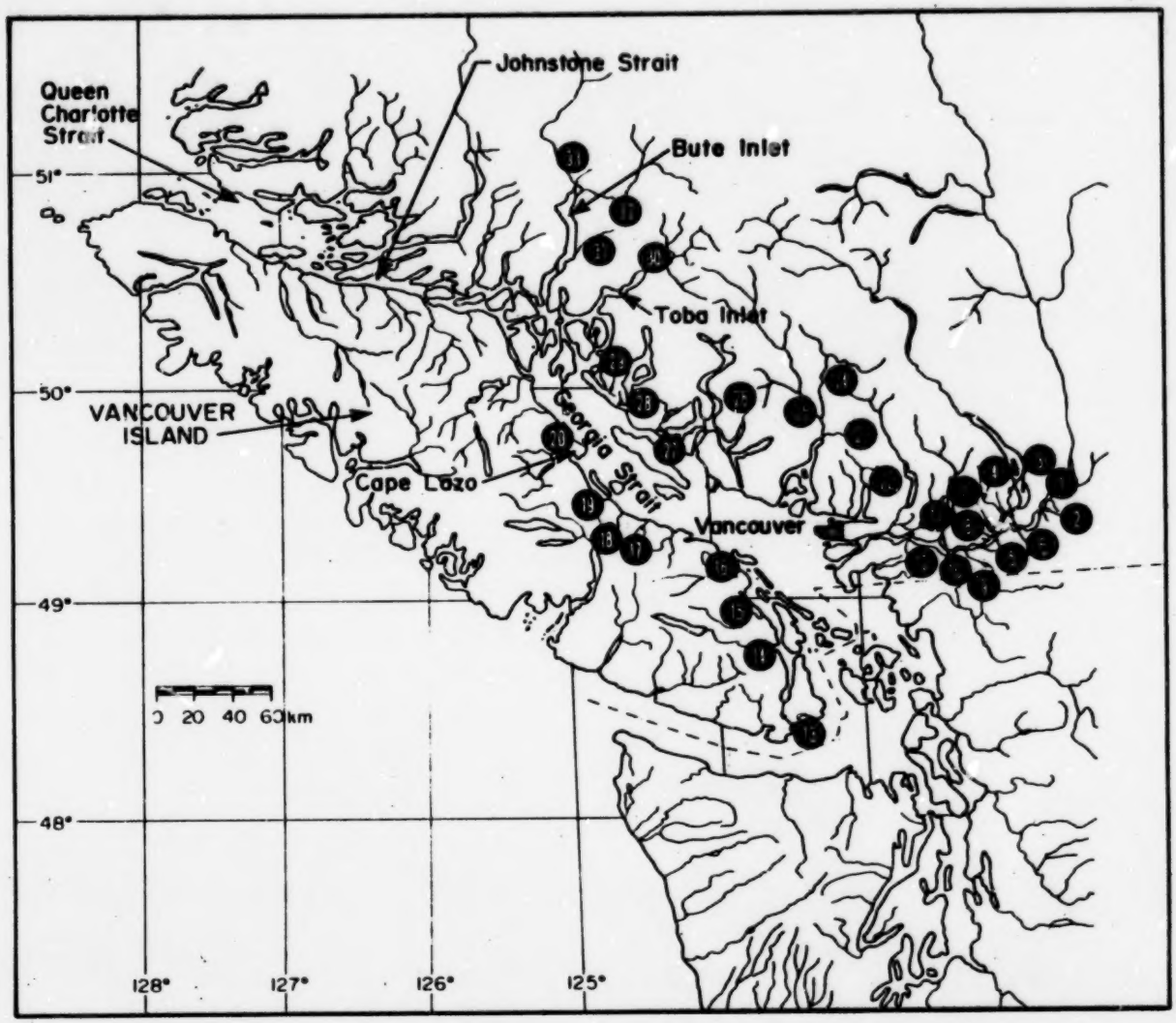

Figure 1. Locations where chum salmon were sampled on the spawning grounds during 1981-1983. Listed in ascending order are: 1) Fraser R., 2) Wahleach Slough, 3) Weaver Cr., 4) Chehalis R., 5) Squakum Cr., 6) Harrison R., 7) Inch Cr., 8) Chilqua Cr., 9) Vedder R., 10) Stave R., 11) Blaney Cr., 12) Alouette R., 13) Goldstream R., 14) Cowichan R., 15) Chemainus R., 16) Nanaimo R., 17) Little Qualicum R., 18) Big Qualicum R., 19) Rosewall Cr., 20) Puntledge R., 22) Indian R., 23) Mamquam R., 24) Squamish R., 25) Cheakamus R., 26) Tzoonie R., 27) Saltery Bay Cr., 28) Sliammon R., 29) Okeover Cr., 30) Toba R., 31) Orford R., 32) Southgate R., 33) Homathko R.

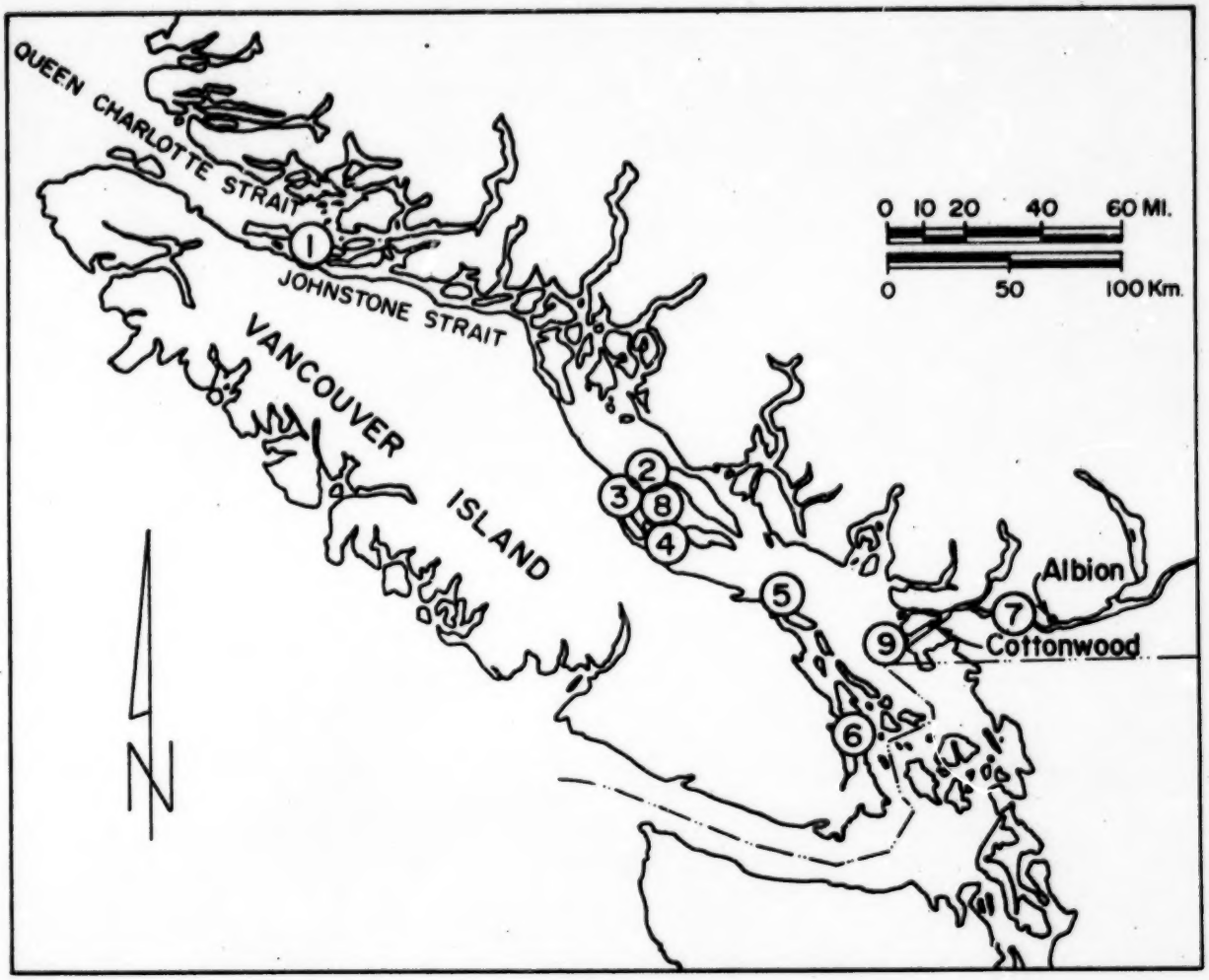

Figure 2. Locations of fisheries sampled during 1981-1983. Listed in ascending order are: 1) Johnstone Strait, 2) Texada Island, 3) Puntledge, 4) Big Qualicum, 5) Nanaimo, 6) Cowichan, 7) Fraser River, 8) Cape Lazo, 9) Roberts Bank.

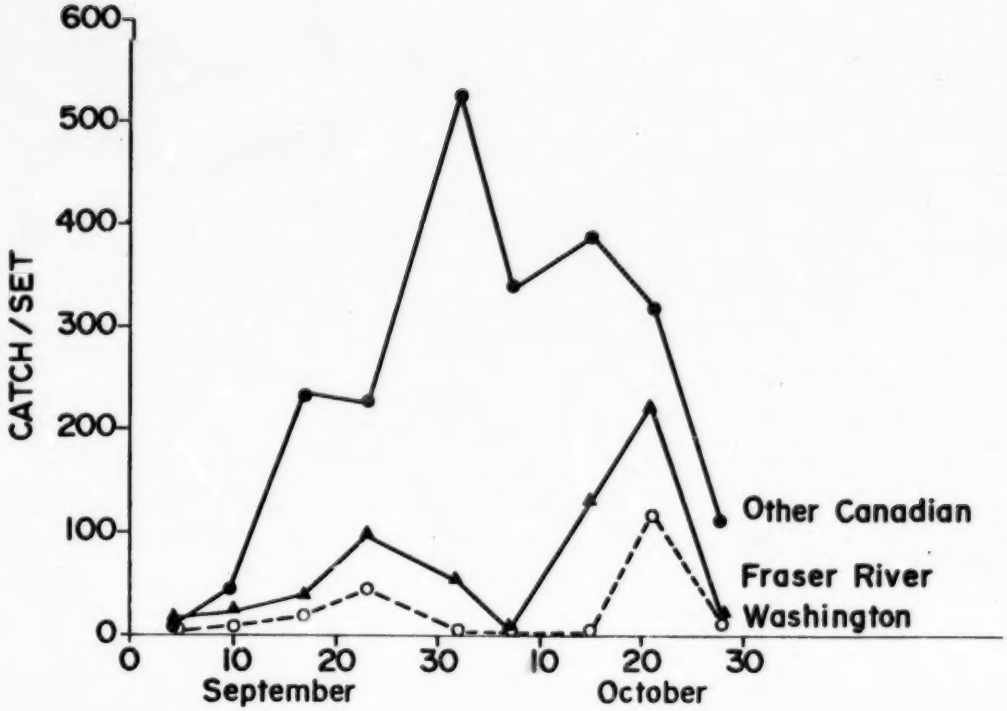

Figure 3. a) Mean weekly catch per set for 3 groups of chum salmon in the upper Johnstone Strait purse seine test fishery during 1982.

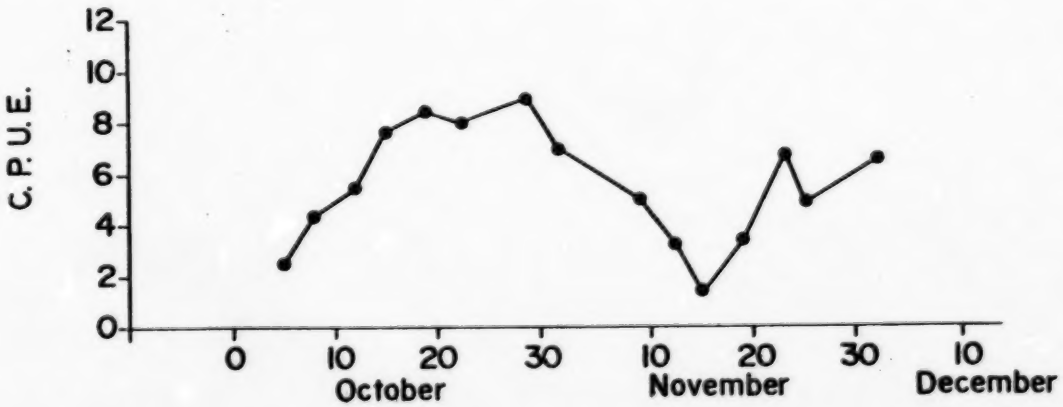

Figure 3. b) Catch per unit effort of chum salmon in the gillnet test fishery at Cottonwood in the Fraser River during 1982.

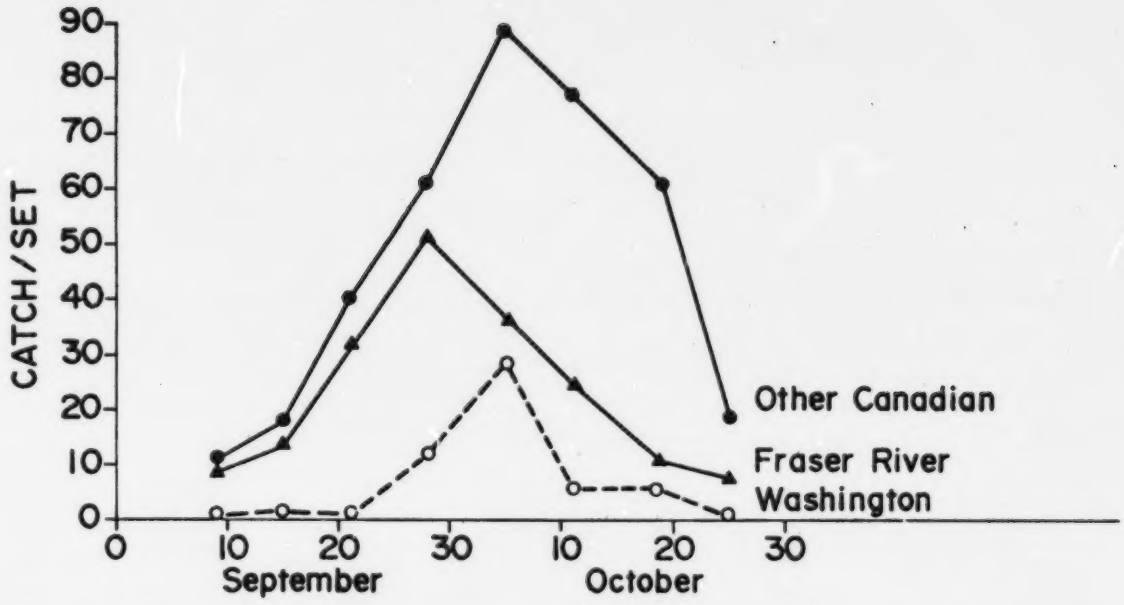

Figure 4. a) Mean weekly catch per set for 3 groups of chum salmon in the upper Johnstone Strait purse seine test fishery during 1983.

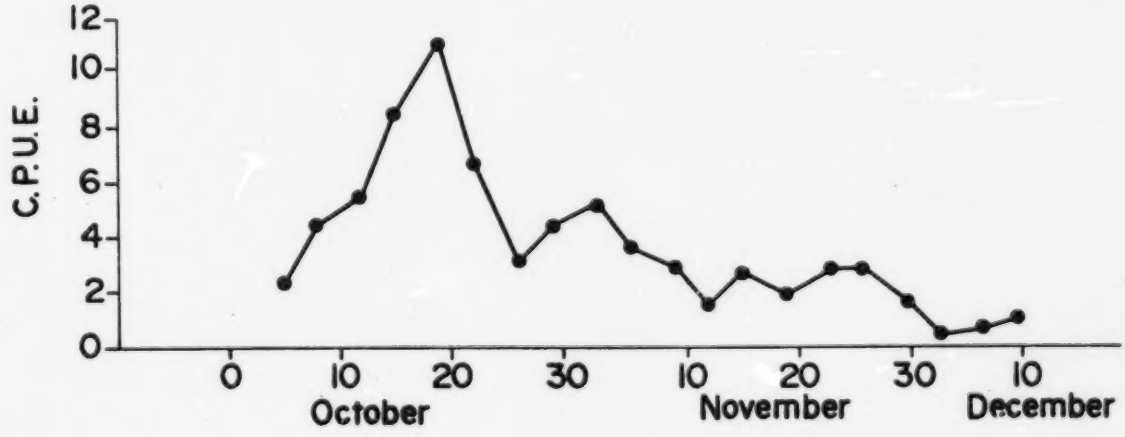

Figure 4. b) Catch per unit effort of chum salmon in the gillnet test fishery at Cottonwood in the Fraser River during 1983.

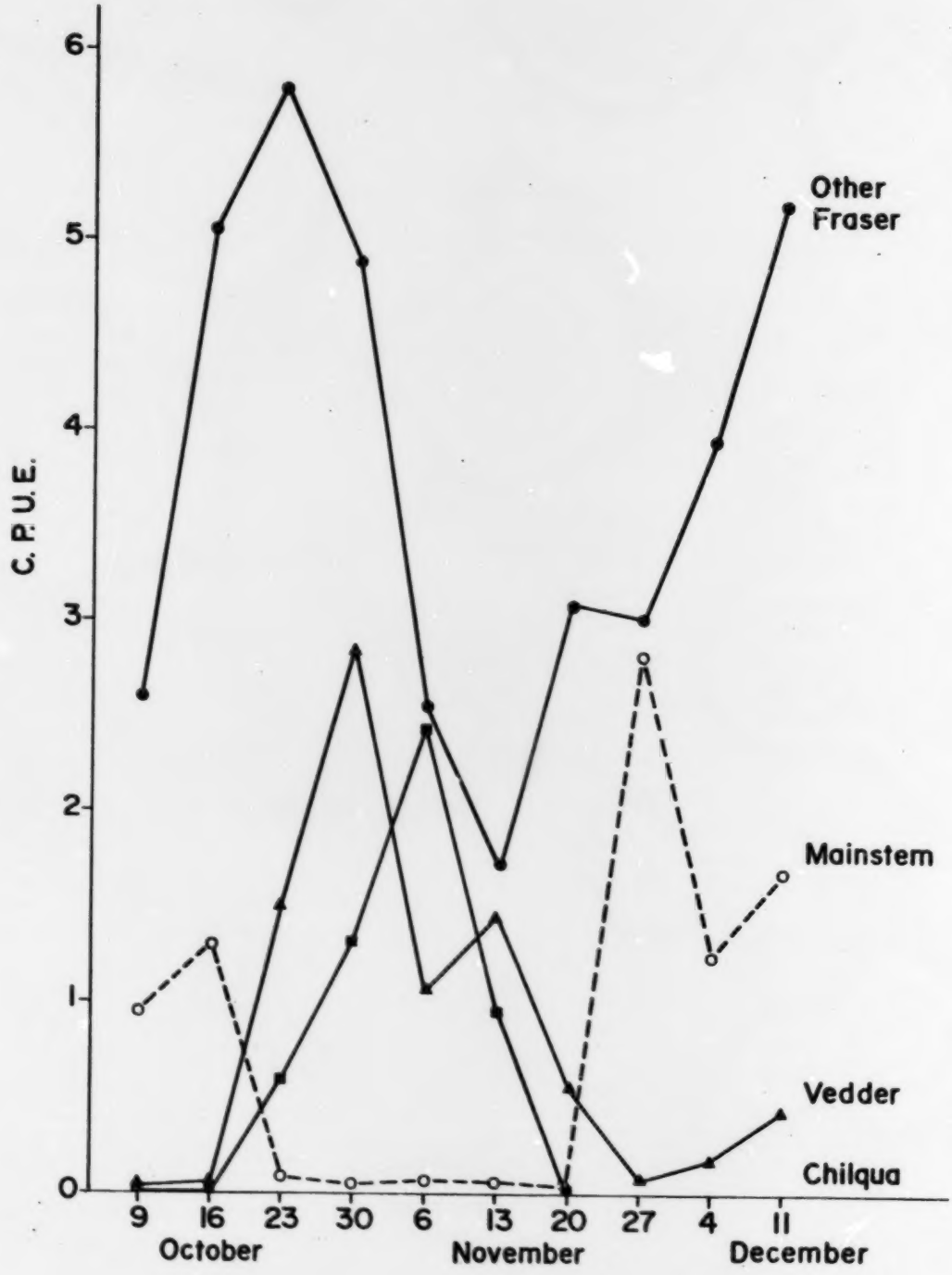

Figure 5. Mean weekly catch per unit effort for 4 groups of chum salmon in the gillnet test fishery at Albion in the Fraser River during 1982.